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## SHORTER ARTICLES AND DISCUSSION

### FURTHER NOTES REGARDING SELECTION INDEX NUMBERS<sup>1</sup>

THE purpose of the present communication is to correct and extend a former paper from this laboratory<sup>2</sup> dealing with the use of index numbers in mass selection operations. In the correspondence which the writer has had with various workers regarding that paper it would appear that a point which it was intended should be emphasized has been rather overlooked. This is that the examples of index numbers therein given for sweet corn and for poultry were intended merely to *illustrate the principles involved*. They were not put forward as the best formulæ which could be devised, even for the organisms discussed. It was pointed out that the particular formula to be used should be devised by each worker to fit his particular needs. Apparently a number of workers have adopted without change the formulæ given in our first paper. I wish again to emphasize that unless these happen to meet exactly the particular needs of the breeder, it is highly desirable that he develop formulæ of his own, involving the same general principle, but adapted to his special conditions.

#### I. CORRECTION OF AN ERROR IN THE FORMULA OF A SELECTION INDEX NUMBER FOR CORN

In our first paper there is an error in one of the equations for the selection index for sweet corn (*loc. cit.*, pp. 397-399).

This error has given trouble to some workers desiring to use this index number in breeding work with corn, and may cause confusion in the future. Doubtless some of those who have used the index in their work have, like the writer, made for themselves the somewhat obvious correction. Nevertheless, to insure that there may be no further confusion it seems desirable to publish a formal correction.

<sup>1</sup>Papers from the Biological Laboratory of the Maine Experiment Station, No. 35.

<sup>2</sup>Pearl, R., and Surface, F. M., "Selection Index Numbers and Their Use in Breeding." *AMERICAN NATURALIST*, Vol. XLIII, pp. 385-400, 1909.

The corn index number has the following formula

$$I_1 = \frac{A + 3B + 2C}{D + E + F^2}.$$

The definition of the variable  $C$  given on p. 393, by an unfortunate slip of the pen, which escaped detection in the proof, as such things will, gives precisely the inverse effect from what it should. The equation *should* read as follows:

$$C = 100 - \frac{100 \text{ times the circumference of the cob at middle}}{\text{Circumference of ear at middle}}.$$

The example on p. 399, which was worked out after the text was written, followed the erroneous text with scrupulous exactitude in theory, but with a slip in the arithmetic. The correct value of  $I_1$  for the ear used as an example is

$$I_1 = \frac{190.0 + 70.5 + 77.6}{21.6 + 2.8 + 0} = \frac{338.1}{24.4} = 13.9.$$

Experience in the use of this index suggests that in the equation for  $C$  given above it may be advantageous to substitute "diameter" for "circumference" in each case. The diameters can be much more easily and accurately measured and they probably give a better appreciation of the relative kernel depth than do the circumferences.

## II. A SELECTION INDEX NUMBER FOR BEANS

The writer has under way at the present time some breeding experiments with a very interesting variety of beans, known locally as the "Old-fashioned Yellow Eye." It is a variety apparently scarcely known now outside of northern New England. Owing to certain defects it has been replaced in most of the bean-growing sections of the country where formerly grown by the Improved Yellow Eye, a perfectly distinct and in many respects inferior type. From the standpoint of experimental genetics the old-fashioned yellow eye bean promises to furnish material of great interest and value in the unraveling of such problems as pattern inheritance, the effect of selection in pure lines, etc.

Aside from the technically biological considerations, however,

this bean possesses much economic significance in Maine. It is esteemed above all other sorts for baking purposes, and if a strain could be developed which would possess (*a*) high yielding qualities, (*b*) reasonable disease resistance and (*c*) earliness and uniformity of maturing it would be of great value to the bean growers of the state. In connection with the purely biological studies an attempt is being made to see whether a pure line possessing these desirable qualities may not be found.

In this specific breeding problem we obviously have the conditions which demand the aid of selection index numbers. Several characters (not *one* only) must be concurrently selected. An estimate must be formed in each case of the *net* worth of an individual plant (or of a biotype), taking into account at least all of the three factors named. In order to do this impartially and accurately a selection index number has been devised.

In deriving this bean selection index a general equation of a slightly different type than that discussed in our former paper has been employed. In that paper (*loc. cit.*, p. 389) the general formula suggested is

$$I_1 = \frac{ax \pm by \pm cz \pm \dots \pm uv}{a'p \pm b'q \pm c'r \pm \dots \pm n't}.$$

In the case of beans (and very likely this may prove true for other plants and animals as well) it has seemed desirable to form an index number on the plan of the following type of equation:

$$I = \frac{axy \pm bwz \pm \dots \pm nuv}{a'pq \pm b'rs \pm \dots \pm n't}.$$

In this equation, as before, *a*, *b*, *c*, . . . *n*, and *a'*, *b'*, *c'* . . . *n'* are constants, given arbitrary values in accordance with the scheme of weighing adopted, and *x*, *y*, *z*, *w*, *u*, *v*, are variables which measure characters increasing in desirability (from the breeders' standpoint) as their absolute magnitudes increase, while *p*, *q*, *r*, *s* and *t* are variables measuring characters which decrease in desirability as their absolute magnitudes increase. The variables specifically taken account of in the bean selection work are:

*Y*—Absolute yield. The weight in grams of dried shelled beans per plant.

$V$  = Relative yield. The percentage which  $Y$  is of the weight in grams of the whole plant. This factor measures the degree to which the plant transforms its food materials into seeds rather than into foliage parts.

$P$  = Number of pods per plant.

$B$  = Mean number of beans per pod.

$D$  = Disease-maturity index. The percentage which the number of perfectly matured beans free of disease (anthracnose) is of the total number of beans originally set in the pods. This measures the degree to which the *performance* of the plant in seed production approaches its *promise* in that regard. It does not separate disease resistance from earliness and completeness of maturity, but from a purely practical standpoint this is not essential. By making separate counts of diseased and immature beans it would be possible to take account of each of these factors by itself. It must be understood further that the separation of diseased beans is not absolutely complete. Only those are counted as diseased which show to the unaided eye evidence of anthracnose infection. It has not been found feasible as yet to get a simple and satisfactory measure of the degree of attack of other bean diseases. Hence, for the present, only anthracnose is being taken account of *specifically* in the selection index number.

These variables are combined in the following bean selection index number:

$$I = \frac{YP + BV}{5(100 - D)}.$$

The values taken by this index number for a particular strain of Old-fashioned Yellow Eyes are shown in Table I.

From the table it is clear that the index may take a rather wide range of values, depending upon the character of the plant. Further, the value of the index is obviously not unduly influenced by any particular variable. The high index values seem clearly to indicate the plants which are the best, *taking all things into account*. This, of course, is the goal sought.

It is of interest to note the values taken by the index in the case of a bean of quite different type, namely, a white field

TABLE I

VALUES OF THE SELECTION INDEX NUMBER FOR A SERIES OF PLANTS OF MORSE'S OLD-FASHIONED YELLOW EYE BEAN, TOGETHER WITH THE VARIABLES ON WHICH THE INDEX DEPENDS

Plant No.	Selection Index	Absolute Yield	Yield Index	Mean No. Beans per Pod	Mean Bean Weight	Total No. of Pods	Disease-Maturity Index
87 <sup>3</sup>	.60	5.5 gms.	45.83	2.00	.55 gms.	5	60.00
85	.79	12	36.36	3.90	.47	10	33.33
86	1.24	10	41.67	3.43	.50	7	62.50
61	1.31	15	50.00	3.77	.39	13	41.45
98	1.37	7.5	41.67	3.20	.58	5	75.00
95	1.51	11	56.40	2.73	.33	15	57.77
59	1.56	13	54.17	3.78	.55	9	58.82
76	1.73	12	46.15	3.42	.43	12	54.03
62	2.00	16.1	49.53	4.33	.50	9	64.10
84	2.08	13	50.97	3.58	.43	12	67.44
71	2.58	24.5	57.64	3.47	.56	15	55.98
80	2.92	18	59.99	2.87	.49	15	69.77
89	3.26	20.5	52.58	3.71	.50	14	70.37
55	3.43	19	59.38	3.69	.42	16	69.49
69	3.73	21	59.99	3.73	.57	11	75.61
92	3.73	12	59.99	3.57	.57	7	84.00
90	3.83	19.5	59.10	3.33	.53	12	77.50
56	3.97	30.9	59.42	4.33	.47	18	58.97
63	4.17	23	51.10	4.53	.41	17	70.13
75	5.35	39	59.99	4.07	.47	27	55.86
81	5.51	27	64.27	3.18	.51	17	75.93
68	7.32	27	59.99	3.42	.46	19	80.38
70	7.37	26	61.16	3.59	.46	17	82.06
60	7.56	19	55.07	3.38	.36	16	87.04
78	8.47	29	61.70	3.19	.46	21	80.97
66	8.79	30	63.17	4.14	.56	14	84.48
67	9.42	23	52.88	3.68	.34	19	86.59
83	9.50	26	59.10	3.14	.43	22	84.06
82	10.09	30	61.24	3.67	.46	18	98.48
97	10.38	50.5	44.11	5.42	.29	41	57.21
79	15.30	30	62.50	3.48	.43	21	88.93
73	17.04	38	60.31	3.89	.42	26	86.14

pea bean. Table II gives the index and component variables for a series of plants of such a variety.

The range of values here is large. The extremely high values are probably much larger than will ever be obtained for a bean of the yellow eye type, though it is rather risky to make such a prophecy. Two factors help in reaching such high index values in the case of this variety. One is the tendency to prolificacy, there being relatively many pods per plant and beans per pod. The other is the rather high disease resistance of the

<sup>3</sup> Plant injured by cut worms.

<sup>4</sup> Plant injured by cut worms, but subsequently grew.

plants. They mature, apparently free from disease, a large proportion of their seeds.

TABLE II

VALUES OF THE SELECTION INDEX NUMBERS FOR A SERIES OF PLANTS OF SNOW FLAKE FIELD BEANS

Plant No.	Selection Index	Absolute Yield	Yield Index	Mean No. Beans per Pod	Mean Bean Weight	Total No. per Pod	Disease-Maturity Index
186 <sup>4</sup>	3.09	7	31.82	4.13	.21	8	87.88
192 <sup>4</sup>	4.42	23	46.95	5.30	.16	33	54.42
187	6.31	6.5	44.82	5.86	.17	7	90.24
191	12.25	38	56.72	6.06	.24	34	73.30
183	12.86	9	54.56	4.10	.22	10	95.12
190	25.44	55	48.24	5.10	.30	42	79.91
188	30.72	60	47.80	5.35	.32	40	82.71
184	71.98	50.5	57.14	5.64	.19	52	91.81
185	101.12	40	57.14	5.35	.22	34	96.71

Of course, the index numbers may, strictly speaking, be compared only among plants of the same variety. The absolute desirability of a variety for a particular purpose depends upon many other factors not taken account of in the index number. These numbers can not be used directly and solely as measures of the relative worth of varieties.

It is hoped that this bean selection index number or some modification of it may be found useful by other workers. It will, at any rate, serve to illustrate further the adaptability of the general idea of such numbers to a wide range of practical selection work. In the present instance a selection index number is applied to the measurement of the relative worth of different distinct biotypes, rather than in the mass selection of fluctuating variations, in which latter type of work such numbers were shown in our former communication to be useful.

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